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VOL. XIII OCTOBER, 1919. No. 8

Frontispiece
Sir David Gill

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Mr. H. C. B. Forsyth, 303 Leeson and Lineham Block, Calgary, is to return to Scotland shortly, and wishes to dispose of his 3-inch refractor. The O.-G. was recently refigured and the equatorial mounting has divided circles.

Upon request, made previous to publication of article, Contributors will be supplied with 50 Reprints in covers free; above that number will be charged at actual cost.

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PLATE IV.

SIR DAVID GILL, 1843-1914.

From a photograph taken by Professor A. B. Macallum at Pretoria during the Meeting of the British Association for the Advancement of Science in South Africa in 1905.

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SIR DAVID GILL, K.C.B.—THE GROWTH, THE WORK AND THE CHARM OF A REAL ASTRONOMER.

BY JOHN A. PATERSON.

CENTURIES ago a man rich in mind and power and wealth, holding sway over a great nation and favored of God, made this weighty statement, "Seest thou a man diligent in business, he shall stand before kings, he shall not stand before mean (that is common) men". Later on in the world's history a Scottish philosopher gave utterance to another weighty statement, "Produce, produce, produce something, even if it be but the pitifullest infinitesimal fraction of a product, produce it in God's name —the only monster in this world is the idle man. Blessed be the man who hath found his work, let him ask no other blessedness." Of the two, I frankly confess I prefer Carlyle to Solomon, for his proposition is more striking, it is more rugged, it is more democratic. The subject of our thought tonight illustrates each epigram. David Gill, the watch maker's apprentice, was truly diligent in his business and he did verily stand before the Queen of England, both good and great, and received at her hands a knighthood and thus "bore his blushing honours thick upon him." But in a yet nobler and higher

sense he stood not *before* but *among* kings and was the friend and confidant of prophets, priests, princes and kings of Science, divinely endowed with the very highest intellectual power. For he inhabited a world where dwelt such a galaxy as Lord Kelvin, Clerk Maxwell, Knobel, Darwin, Christie, Lockyer, Hale, J. Couch Adams, the discoverer of Neptune, Lord Lindsay, Newcomb, Airy, Huggins, Struve, Dollen and many more. These were kings indeed. He also not only touched but entered into the very Canaan of a social and aristocratic kingdom where dwelt such men as Sir Bartle Frere, Cecil Rhodes, Earl Grey, once Governor-General of our Dominion, the Khedive of Egypt, Lord Crawford and many more. He also fully illustrated in his life and work the Carlylean maxim, for he was indeed a producer in the realm of Astronomical Science; his work with the Cape heliometer, determination of the solar parallax from observations of Mars, geodetic survey of Rhodesia, his measurement of the arc of a meridian, observations on the comets of 1880, 1882, 1884, 1892, 1899, 1901, 1903, 1904 were but a few stars in the crown of his success. These were indeed far more than the "pitifullest infinitesimal fraction of a product." And he verily found his work, and he therefore needed no other blessedness, although he rejoiced in many more. With David Gill astronomy was almost a religion. But in the words of Professor George Forbes his biographer "the reverence for his chosen science was tempered by human sympathies"; and we have a most interesting record of his delightful social and democratic life, his humour, his enjoyment of the world and his varied employments, among which even deer stalking occupied a special place. Not only was he skilled in shooting stars, but was an expert in shooting deer, and thus the range of his life was large and varied. He looked at it from so many angles that he was indeed a human polygon. He was not an astronomer for gain, or even for professional renown, or self advancement. He was an astronomer because he could not help it. He sang the song of his life just "as the linnets sing". In a word he did not live by astronomy but he lived for astronomy. To him it was not only a sentiment but a sacrifice, not only a feeling but a fact, not only an emotion but an energy. Duty is a word very much exalted in general estimation, but it is cold, metallic, and hard, although admirable. A man for duty only goes at his work with

a tense nerve, a square jaw, a stiff back and an iron resolution, and he no doubt may succeed and he deserves applause. It is hard work, it is pumping up results from some lower depth with infinite labour and perspiration and even pain; but let love animate him and his life is changed, and instead of a laborious uplift his life product pours down as from a crystal fountain, freely, fully and joyfully. And joy is so much better than pain. Tennyson puts it thus:

> Love took up the harp of life, and all its chords it struck with might,
> Struck the cord of self, which trembling passed in music out of sight.

Gill loved his profession and the whole world loves a lover, he worshipped his science and the whole world reveres a worshipper, even indeed if they do not agree with him or even understand him. Moreover, like most men of truly scientific mind, he was an earnest Christian, which characteristic was no doubt helped by his Scottish ancestry and education. General Gordon, known as "Chinese Gordon", bore his own testimony to him for he found a responsive chord to his own heart in Gill's character. On a certain occasion after leaving Gill with a friend he said quietly, as he jerked his thumb towards Gill, "of such is the salt of the earth". Could any man say more?

Following such men as Newton, Kelvin, and Clerk Maxwell, he had, to use Maxwell's words, "a contempt for that pseudo-science which seeks for the applause of the ignorant by professing to reduce the whole system of the Universe to a fortuitous sequence of uncaused events." To such men God was not "a majestic bundle of abstract nouns loosely tied up in impersonality." In his study of Nature he rose from Nature up to Nature's God.

In illustration of his religious character it is recorded that—A dear friend, writing to him in great trouble, received the following reply:

"I have the very deepest sympathy with what you tell me of your inner life—and am thankful that you have found the only solace and guide in all such troubles. We, however, never can have by instinct or by any other way a knowledge of God's purposes towards us—we can only try to do what we believe He would wish us to do.

"In our affections and the closest and dearest relations of life, instinct, if not rendered unreliable by passion or self-interest, is

generally a good guide . . . The simplest rule in all life is to ask one's self what Christ would have done in the circumstances, and then try to do what you honestly believe He would have done. None of us can always do that—but the better we try the better we shall bear and the better we shall be.

Often the things that seem to be the greatest trials in life turn out in the end to be the greatest blessings. You cannot grow a hardy flower in a hothouse—it is the trials of life that make the moral training, just as it is the poor soil, the winter blast, the unwilling harvest, that make the hardy Scot about whom we said not a little on Saturday night at St. Andrew's dinner."

And on another occasion Gill said to the Editor of "Great Thoughts":

> There is no subject which appeals, or ought to appeal, more strongly to the imagination than that of Astronomy, nothing which lifts men, or ought to lift them to a higher plane of thought, or gives them a better grasp of the infinite power of the Creator: nothing that exemplifies more completely the unity of design that exists in Nature; nothing that teaches more the Christian lesson of humility and yet, at the same time, affords the highest proof of the intellectual possibilities open to man.

Gill's earthly life began in 1843 and he passed into the great Eternity in 1914. He first looked on the world in the City of Aberdeen, which has produced many other eminent men. His grandfather was a watchmaker, his father was a watchmaker and he himself became a watchmaker's apprentice by his father's direct command, and that direction was so faithfully obeyed for such a period as put all thought of a Cambridge degree out of the question, though he had in him the stuff out of which senior wranglers are made. He attended some sessions of Marischal College, Aberdeen, and was there inspired by contact with Prof. Clerk Maxwell which led to a lifelong friendship between them.

Repairing watches did not suit young David's inclination—we cannot drive a sawlog up-stream, and Pegasus resents being harnessed with a common dray-horse, and so it came about that David drifted away from the watch-maker's bench and soared to the stars. Professor David Thomson of Aberdeen exercised a mighty influence over the career of this weary young watchmaker and budding astronomer. As to the mathematical work of the

Scottish universities, it is worthy of note that in ten successive years in his day they sent to Cambridge five men who gained the senior wranglership in the mathematical Tripos, which is the highest honour Cambridge could give her sons. Gill never became a trained mathematical astronomer, his career had given him no opportunity to cultivate pure mathematics, but he nevertheless possessed what was more valuable, that is mathematical intuition or "νους." If he had devoted himself to the worship of the "cross-grained Muses of the cube and square" he would doubtless have become an equally great high priest in that service as he became a most noted and successful conqueror of the skies in the realm of observation. There is no doubt that the facility he acquired in his earlier years in the use of his fingers, handling tools, and executing delicate construction, and experience in mechanical drawing were of untold value to him, and trained him for the construction of delicate instruments and complicated machinery by which he assailed celestial problems, and, with more success than the fabled giants of old, not only reached for but grasped the sovereignty of the stellar universe.

His biographer Professor Forbes divides his life into three periods:

(1) 1843-1879—The growth of a real Astronomer.
(2) 1879-1907—The work of a real Astronomer.
(3) 1907-1914—The charm of a real Astronomer.

At the age of twenty or thereabouts Urania, the Muse of Astronomy, touched his imagination and then fired him into action. He formed the idea of securing an accurate time service at Aberdeen. He met Professor Piazzi Smith at Edinburgh Observatory and succeeded in interesting Professor David Thomson in his efforts. A portable transit instrument, long out of use, was discovered at King's College, Aberdeen, the sidereal clock was overhauled and fitted with an apparatus for the electrical control of other clocks and the young watchmaker had a novel occupation in his leisure evenings. He soon developed further ambitions, and mounted equatorially a second-hand silver-on-glass mirror of twelve inches aperture and ten feet focal length, making the driving clock with his own hands. With this he made many excellent photographs of the moon. At that time Lord Lindsay, son of the Earl of Crawford,

was planning to erect an observatory at Dun-Echt, near Aberdeen, and became naturally attracted to this young Scottish enthusiast—he could not yet claim the title of Astronomer—and Gill became in 1872 the director of the Dun-Echt Observatory. This involved his giving up a flourishing lucrative business, and compelled a heavy pecuniary sacrifice, and with his young wife he took his first upward step into a career that promised no earthly emoluments. He, so to speak, burned his boats behind him and without thinking of fame, yet felt its impulse and followed the beckoning of his angel unconsciously forward to unknown conquests—and to gain crowns undreamed of. He was director of this infant observatory for four years, and there he designed and installed its fine equipment which was a fitting prelude to his greater work in after years at the Cape. At this period he made a visit to the island of Mauritius on the occasion of the transit of Venus in 1874. His use of the four inch heliometer began in preparation for this expedition; this heliometer was afterwards taken to the Cape and was the instrument by which many of his most celebrated researches were made until replaced by a larger one of seven inch aperture which cost £2,200. It may be profitable and even necessary here to define what a heliometer is. It is shortly described as an instrument for the accurate measurement of small angles in the heavens, consisting of a telescope whose objective is cut into halves that may be slid past each other so as to form two images of any object toward which it is pointed. The angular distance between two stars is determined by measuring the displacement of the halves of the objective necessary to cause one image of one of the stars to cover one image of the other star. In the hands of Gill, and especially in his great researches on solar and stellar parallax, it has been recognized as an instrument of the very highest accuracy, measuring the distance between stars correctly to less than a tenth of a second of arc. That angle was said by Sir George Airy, the Astronomer Royal, to be the smallest thing in the world. The wonderful work that Gill did with his heliometer was such that as he exhibited sheet after sheet of results he asked: "Will Airy deny now that there is such a thing as a hundredth part of a second of arc?" And in this connection no one enjoyed the following joke more fully than the Cape Astronomer. This small angle referred to (0″.01) is less than

that subtended by a three-penny bit at a distance of one hundred miles. Gill expressed it so in a lecture before a company of Marine Engineers as the most refined measurement attained by astronomers, and he thoroughly enjoyed narrating how the chairman at a dinner in the evening, when proposing the lecturer's health, said there could be no doubt about his nationality, because nobody but a Scotsman would bother about a three penny bit a hundred miles away. This sally had its pith in the fact that Gill's broad Aberdonian Doric and rolling r's not only revealed but proclaimed his nationality to the most casual hearer. But I am anticipating the sequence of history.

In 1877 Gill undertook an expedition to the Island of Ascension with the object of determining the parallax of the sun by observations on Mars, for in that year Mars was nearer to the earth than for the next hundred years and he wanted to do the best that could be done. Before this it had been thought that observations on the transit of Venus would unlock the secret and give the most accurate measurement of the sun's parallax and hence of the sun's distance from the earth. It is interesting to read how nearly the whole expedition was frustrated by an accident to the heliometer. It was mounted in the meeting room of the Royal Astronomical Society and Gill had been working with it and adjusting certain parts of its mechanism when suddenly a loud crash was heard. There stood the iron pillar, but the valuable instrument lay on the floor, and Gill, his face buried in his hands, down which blood was trickling as he had made an ineffectual clutch at the falling mass, called out that everything was ruined: himself, the instrument, the expedition. But his resolution and vitality revived and he said: "Let us see what can be done." He found that the divided object glass protected by a metal cap had escaped injury, but the eye pieces with their tubes were shattered. In the end everything was repaired and the expedition was an entire success. The island of the Ascension is a barren rock, near the island of St. Helena, inhabited by turtles; it is a sort of cinder or clinker ejected from some extinct volcano, and there Gill and his wife with a small party remained for six months in eager search for the secret of the sun's distance from the earth. At that time it was known to be between ninety and ninety-six millions of miles. Astronomers required to know it

within a thousandth of its amount. The result was a parallax of 8″.783, and this gives the sun's distance as 93,080,000 miles. Later on at the Cape, by observations on minor planets, he worked out the parallax at 8″.802, and the sun's distance at 92,870,000 miles, which has since been universally accepted. The problem was further attacked by using minor planets, Iris, Victoria and Sappho with a result differing from this by only 1/200 of a second of arc. The importance of this measurement is very great because the sun's distance from the earth is the foot rule or unit of distance for all celestial measurements. With that as a basis the distances of all the planets can be ascertained by applying Kepler's law, as proved mathematically by Newton that the squares of their years vary as the cubes of their mean distances. The Gold Medal of the Royal Astronomical Society was awarded him in 1882 for his work on the solar parallax, and in the same year he received the Valz Medal of the French Academy of Sciences. In all this great work his charming wife shared with him his hopes, disappointments and triumphs and on that barren rock helped him in all his work in wresting from nature her deeply hidden secrets.

But Gill's greatest life work was when in 1879 he was, in the face of strong competition by W. H. Christie (afterwards Sir Wm. Christie, Astronomer Royal), the then chief assistant of Greenwich Observatory, appointed Her Majesty's Astronomer at the Cape of Good Hope. This position gave him his great and enduring fame as an observer and discoverer in the great realm of Astronomical Science. He was soon acclaimed as one of the prophets, priests and kings of science. Discoveries are often the result of great labour and inductive or deductive reasoning, but they are sometimes the result of accident. The great observing astronomer Kepler discovered his three great laws by a laborious compilation of observations—in a word by induction. Newton, the great mathematical astronomer, did not discover but deduced the same laws by deductive reasoning without observation; he could have worked them out even if he had been physically blind. But some happy chance has often been the parent of a great discovery, although slowly moving Oedipus with the lame foot solves the riddle of the fabled Sphinx, yet swiftly flying Mercury lights easily upon the topmost height of Olympus. Saul went forth to find his father's asses, and behold

he found a kingdom. Astronomy has also its corresponding counterpart. Sir Wm. Herschel, while attempting to measure the distances of double stars, discovered their orbital motions. Astronomers, as we know, were before Bradley's time puzzled at certain irregularities in the apparent motions of fixed stars in a most unaccountable way; they refused to appear where stars of regular habits ought to have appeared. While sailing on the Thames he observed the shifting of a vane on the mast as the boat altered its course, and having been assured that the motion of the vane meant that the boat and not the wind had altered its direction he realized that the position taken by the vane was determined by the motion of the boat and the direction of the wind. From that slight incident he transferred the explanation to the sky, and proved that the apparent shift in the position of a star was referred to a combination of the orbital movement of the earth and the velocity of light, and thus another of Nature's secrets was dragged from her unwillingly and the theory of the aberration of light—a corner stone in the edifice of Astronomical Science was established. When that curious law called Bode's law showed an extraordinary relation of the distances of the planets from the sun, the sequence of which was broken by a blank between Mars and Jupiter, Astronomers sought in vain to discover the missing member of the solar family, the lost sheep of the planetary fold, but had given it up and the perfection of Bode's law was unsatisfied. But Piazzi, when laboriously charting the stars in 1801, accidentally discovered the first minor planet—and Ceres took her place on the star maps as the first of the great family of asteroids which had, with such successful modesty, for untold centuries eluded the observation of their big sister the earth. But the most wonderful example of great discoveries from some accidental complication of circumstances is the well-known story of Newton's discovery of the theory of gravitation when he was driven by a prevailing epidemic to visit the country, and then and there some kindly gust of sportive wind loosened an apple from a tree which fell at the feet of the great philosopher, and awakened in his mind the question, why is this piece of matter here? And why did it fall? So also was it in 1882 when a brilliant comet appeared in the southern heavens at the Cape Observatory so brilliant that it was seen in full sunlight even near the sun's edge.

Gill wished his friends in England to share his joy, and it suddenly occurred to him to strap an ordinary portrait camera to the clock driven equatorial. He thus followed the comet for hours, keeping the cross-wires of the telescope on the head of the comet. The result was a tremendous advance in the pursuit of Astronomical Science and photographic star maps were made, and observers no longer were confined to fleeting observation, but now the possibilities and potentialities of the telescope were both enlarged. The retina of the human eye, although a matchless optical instrument, no doubt receives impressions but cannot hold them, but now the photographic plate receives impressions more completely than human vision, and holds them firmly, so that they can be conveyed from observatory to observatory, from continent to continent, from year to year and from this century to future centuries. The sun, the moon, the stars each writes its own story in luminous letters through the camera and perpetuates what it says. Photographic stars whose light cannot affect the retina of the eye, sensitive though it is, yet in hours of exposure reveal themselves on the sensitive plate of the camera, and are thus discovered and held. Astronomical observatories are no longer necessary for the education of the multitude, but their plates and charts are multiplied, and thus the wonders of the heavens flash their glories where they were formerly unknown and unappreciated. In very truth the branches of the tree of knowledge are brought down so low that the humblest man can reach up and grasp the fruit. Thus is the world enriched. All thanks to the comet of 1882 and to David Gill, this product of the watchmaker's bench. Thereupon was created the C.P.D., the "Cape Photographic Durchmusterung", or star catalogue. That started Dr. Barnard at the Lick Observatory to strap a portrait camera to the big equatorial, and, by eye correction of the driving clock, to produce those wonderful pictures of the Milky Way, and also set the greatest Observatory of Paris to produce those marvellous pictures of the moon that have made the moon a more familiar and friendly neighbour than ever before.

It was about this time that David Gill and Simon Newcomb, the great mathematical astronomer, became personal and scientific friends, and as iron sharpeneth iron, each of them became brighter and clearer. The great Scottish observer and the equally great

American theoretical astronomer found their counterpart each in the other, and each in his own way added many a beautiful pillar or graceful arch or solid column to the great temple of astronomical knowledge. It was really an *entente cordiale* between two great scientists of Anglo-Saxon blood. But they did not always agree; great men in any walk of life do not always agree. Gill would start a subject with Newcomb and then say: "There is where I differ with you. Now you give me your reply and we'll have a scrap." So they held different views as to the Transits of Venus, the last decimal place in the mass of Jupiter or the Moon, or in the constant of aberration and many other vital points in gravitational theory.

Among the princes of science who had the privilege of Gill's friendship was the great Dutch astronomer, Professor J. C. Kapteyn of Groningen, who became the highest authority on stellar motion investigations. He became a collaborator with Gill. The Cape astronomer supplied the plates and the Dutch astronomer undertook the measurement of the plates, the computation of the results and the formation of the Star Catalogue. It was indeed a happy combination. Kapteyn's greatest discovery in cosmical astronomy was announced first at St. Louis in 1904 and then at the Cape in 1905, when the meeting of the British Association was held there. This discovery was that the majority of stars near enough to us to show proper motion are moving in two great swarms in nearly opposite directions. The greatest authorities state that this great discovery has revolutionized our conceptions of the stellar universe, and no doubt it is the mere prelude to greater revelations yet to come. For the progress of the science of astronomy is illustrated by the story of a great painter who was asked what was the greatest picture he had produced and his reply: "That one I am about to paint." The greatest astronomical discovery made is the one which will yet be made. That is paradoxical, but science grows from more to more.

In 1887 Gill attended the Congress of Astronomers at Paris, where he was one of fifty-six units, but he little realized, although the other fifty-five did, that in knowledge and experience of the production and measurement of stellar photographs, and in consideration of their problems he was a very Saul among his fellows. So that from that year to 1914, the date of his death, the members

of that Congress or Comité Permanent would seek to be guided by his judgment towards the completion of the Astrographic Chart and Catalogue. He returned to the Cape in 1887 happy in the possession of his great heliometer and in the reflection that by the acclaim of the great astronomers of the world he had been assigned a position in the great astrographic work, and thus he realized a new feeling of power to do yet greater service. Next to his wife he loved his heliometer, and she records that when in his observatory after spending some hours with his second love, getting data for star distances, he would come into the house in the "wee sma' 'oors ayont the twal'" shouting and singing, and his wife recorded that he was just "daft laughing and joking and so it will be as long as his eye can look through a telescope." This practice would no doubt have been regarded as very objectionable and open to conjugal reproof by a less sympathetic wife, but it is doubtless more admirable to be uplifted with the joy of stellar parallaxes than to be lifted with that cheerfulness and alacrity of spirit that are derived from bottles taken from a cobwebbed cellar and the corks drawn out. The real character of a man is best known when he is off his guard and not posing under restraint or attitudinizing for effect upon the public, and thus it was with David Gill, the man as well as the astronomer. In the year 1900 he received from his sovereign the honour of knighthood, which he earned not only by eminent services to science, but by equally great services to the Empire in the South African War. The sound common sense even in political matters of this clear thinking Aberdonian and honorable patriotic Briton were of immense value to the administration of the South African government. Lord Milner and Sir David were close personal friends, and the Astronomer proved not only to be a mere academician but a valuable far-seeing adviser. On March 6th, 1900, he writes to a friend, "The time for three cheers and ten thousand hurrahs has come at last. Ladysmith relieved, Cronje and 4,000 of his men captured, and Kimberley open. It has been a terrible time of excitement. They all came into my room and some twenty-five of us drank the Queen's health and Roberts' and Kitchener's and Buller's and French's in my best champagne, and sang 'God Save the Queen'. I tried to make a speech and could not." An eye witness gives this account of his speech. "He rose to speak,

not a word could he succeed in uttering. After we had waited through two minutes of expectant silence he sat down at the table with his face between his hands and sobbed. It was the most eloquent speech he ever made." The astronomer was also a man, and he was a Celt; the terrible strain of these few years so suddenly relieved shook him to the very centre, as that same South African War and of this last Great War have almost shattered the pillars of many a man's self control. The tidal wave of his feelings overflowed its limits. But to a geographer of the skies, to a searcher for the limits of creation, those combats, mighty as they were, were in Tennyson's words only the struggle of ants "in the light of a million, million suns."

> What are men that He should heed us?
> Cried the King of sacred song;
> Insects of an hour, but hourly work their brother insect wrong.
> While the silent Heavens roll, and Suns along their fiery way
> All their planets whirling round them, flash a million miles a day.

In 1905 the British Association for the advancement of Science visited Capetown. This meeting taxed Sir David's business and organizing energies so tremendously that he hardly ever recovered from the effects of it. He retired from the Directorship of the Observatory in 1907. His work as the Cape Astronomer during these twenty-eight years accomplished three great undertakings involving the highest accuracy attainable:

(1) Geodetic triangulation and the measurement of an arc of meridian.

(2) Observations of minor planets with a powerful heliometer to obtain a final definitive value of the sun's distance from the earth.

(3) Observations of apparent stellar displacements, thus measuring star's distances from us.

This great work is thus described by his biographer Professor Forbes:

The force that attracted him to these three researches was the acknowledged difficulty and refinement of the necessary observations, and his belief in himself.

Probably it never occured to him how intimately these were connected. If we take a broad outlook upon what he actually accomplished in these three directions we cannot fail to be impressed by the completeness of his undertaking. For his own measurements alone, and those under his immediate control, furnished the materials for measuring the distances of many stars, in metres, and comparing

these distances directly with the actual metallic bar which is preserved at Paris as the standard metre.

That he should have been the first systematically to attack the stellar distances, with an instrument which with his own hands and eyes he had proved to be equal to this difficult enterprise, was a splendid thing. But that he himself should have provided all the necessary steps of the measurement and triangulation, from the interior of the *Bureau des poids et des mesures* in Paris, where lies the standard metre, right on by continuous triangulation to α Centauri, Sirius, and a number of other stars, is a feat of measurement which has never been equalled, and is not likely ever to be surpassed.

It may have been an accidental concatenation of circumstances and temperament that led to his doing all this; it is very unlikely that he ever realized that he had accomplished the combined feat. That it was done, and done with such superlative accuracy, has evoked the enthusiasm of all astronomers.

Without dealing with details about precautions, and checks upon the work let us look broadly at a portion of what was accomplished in these three great researches.

First, he procured a measuring bar, transported it to Paris, and measured upon it the exact length of the standard metre.

Second, he took this to South Africa to measure a base line on the ground, a few miles long, and from this base, with a theodolite, he extended his survey by a series of triangles over an arc of meridian.

Third, latitude observations, at the two ends of this arc measured in metres gave him the means of determining the diameter of the earth in terms of the standard metre at Paris.

Fourth, taking a definite portion of this diameter of the earth, as a base line, over which he was carried by the earth's diurnal rotation, he extended his triangulation to the minor planet Victoria. This gave him the scale for measuring the solar system. Thus his triangulation gave him the diameter of the earth's orbit.

Fifth and finally, he still further extended the triangulation which was begun in South Africa, and, using as a base line the diameter of the earth's orbit, over which he was carried by the earth's revolution round the sun, he completed his triangulation from the bar of metal in the Paris bureau to the distant fixed stars.

Thus, without any extraneous help, he measured the distances of the stars with the Paris standard metre.

Stated thus, the stupendous nature of the triple problem captures the imagination. Meanwhile, practical astronomers, studying in sober earnest the voluminous records of the triple undertaking, are uplifted in admiration, not only at the unrivalled skill of hand and eye, not only as the mathematical instinct that guided his steps, but even more at the dogged persistence and steady effort, which enabled him to overcome every obstacle. Other astronomers have had the skill, other astronomers have had the instinct, and other astronomers have had the persistence and steady effort. There are few to whom all have been given to the degree required for the completion of this stupendous work.

In his early years Sir David was a 'crack' rifle shot, and if he had not been appointed as Her Majesty's Astronomer at the Cape would have become eminent as a marksman. At the Cape he was a successful deer stalker and in his later years, when he returned from South Africa, he was always a welcome guest on the moors and deer forests of Scotland and the English coverts. His great skill in observing, his handling the telescope and its many minute appurtenances, his steady hand, delicate touch and clear sight were simply sequences to his skill with the rifle.

On October 1906 Sir David Gill left the Cape but with no signs of failing vigour; on the contrary he plunged into a strenuous life of scientific activity in London. He became President and afterwards foreign Secretary of the Royal Astronomical Society, President of the British Association at Leicester, and in many other positions, became a centre of energy and initiative. Universities and learned societies through the world honoured themselves by ranking him on their Rolls of Distinction. Some of these may be stated: Knight of the Prussian Order pour le mérite; Commander of the Legion d'Honneur, Hon. LL.D. Aberdeen and Edinburgh, Hon. D.Sc. Oxford, Cambridge, Dublin and Cape of Good Hope. Rome, Amsterdam, Petrograd, Washington, Sweden, Boston, Philadelphia, South Africa were proud to inscribe his name on their rolls of fame. Science has indeed no geographical boundaries, no "pools of salt and plots of land" separating her devotees. Indeed we may add that her domain extends through the entire universe, wherever light shines, or orbs roll, or space extends, and also for all time, from when the morning stars sang together down to the remotest hour in the great everlasting. Her kings and prophets form a mighty army.

This address would however be less complete without some references to the human side of Sir David which illustrate the charm of the real astronomer and put him among his fellow-men.

After his retirement, when resident in London, he became what he called "a dress-coat astronomer", and many a table found him a genial companion and a brilliant raconteur. Earl Grey from Ottawa wrote to "my dear Astronomer" and they swapped yarns. Here follows one written to him at Johannesburg by the Earl from Government House, Ottawa:

Here is a story which will amuse you. A Custom House officer put the usual question to an American lady the other day on arrival at New York, as to whether she had any dutiable goods. "No, nothing but wearing apparel," she persisted, and showed some indignation when the Custom House officer, distrusting her word, proceeded to open her box and rummage right to the very bottom. With triumph he pulled out from below her dresses two big magnums of whisky, and holding them by the neck, asked the lady what she meant by saying that she had nothing in her box but wearing apparel. "I stated what was the truth", said the lady, "for you hold in your hand my husband's night-caps!" The official immediately withdrew his claims, and the lady withdrew in triumph.

Can you send me back a better one which I can tell Sir Wilfrid Laurier, whose story this is?

I am much distressed that you are not able to give me a better account of your delightful wife. Please give her every assurance of my continued devotion.

GREY.

Sir David was never at a loss for a *bon mot*, which is saying a good deal for a Scotchman and especially an Aberdonian, as for example:

One evening after his retirement he was a guest at a reception in a certain lady's London house. He and a most distinguished ecclesiastic were in close juxtaposition when their hostess advanced and addressed them in these words: "I want to make the greatest astronomer in the world and the greatest preacher in the world acquainted," and after introducing them, moved off. There was dead silence between the two men for some seconds. Then Gill looked his companion in the eyes, and said with his humorous twinkle: "It is not often that either of us meets such a distinguished man." This broke the ice.

Sir Flinders Petrie recalls a remarkable characteristic story of an astronomer. "At a Royal Society meeting Dr. G. E. Hale was describing his marvellous solar photographs in a single spectral ray. At the end of the address the President asked Sir David if he would say something. He rose slowly to his full height and said: "Wor-r-r-shipful admir-r-r-ation," and sat down again.

Here is another Gillianum. It was after a pheasant shoot, and at the supper when the day ended Gill told this: Two Scotsmen met one another. "Well hoo are ye, an' the wife". "Oh the wife's deid". "Ah so! and hoo was it?" "You see I found her poorly so I just gae her a powther the doctor had aince pit up for me that

I didn't use, and in twa hoors she was deid. Eh man I was terrible glad I had na ta'en it mysel!"

These are a few excerpts from the most interesting biography written by Professor Forbes, to which work I have been much indebted in preparing this sketch. These are only a few illustrations of this many-sided man's character,—a few pictures, so to speak, taken from the wall of his social life which to some degree reflect the charm of his private character. What would life be without humour? It is the slackening of the bow string, it is the mind's vacation which rests and thereby strengthens the mind's vocation. There are no great books, nor any great forces in human life which are devoid of it. As Sidney Smith says: "Man could direct his ways by plain reason, and support his life by tasteless food; but God has given us wit and flavour and brightness and laughter and perfumes to enliven the days of man's pilgrimage and to "charm his pained steps over the burning marle."

Sir David Gill's death followed not long after that of another famous astronomer, Sir Robert Ball, whose funeral he attended and there caught a chill, which eventually carried him off, and on the 24th of January, 1914, he bade goodbye to this proud world and went home. Thus did this great star computer rest from his earthly work and went hence where "the stars wander with golden feet", but yet are all shepherded by Almighty power and guided in their courses by Divine wisdom. And now we for a moment revert to our opening sentence for here was a "man diligent in his business". Astronomy does not suggest repose. It does not say to its votaries "Sleep on now and take your rest." On the contrary it calls us to industry, struggle and achievement. The never ending rush of the spheres rebukes man's idleness, it stimulates action and then energy is contagious. In these ever-circling orbs the Divine being has declared His own forcefulness and made proclamation that whatever man finds to do he should do it with all his might. Nature abhors a vacuum of matter, and these Scriptures of the Sky bid us abhor a vacuum of energy in our lives, and present to us an object lesson of ceaseless activity. Let such a lesson permeate and inspire each life, and let no one hide his talent, even if it be only one, but let it "produce something even if it be but the pitifullest infinitesimal fraction of a product". And thus we end where we began.

THE PROBLEM OF ISLAND UNIVERSES.*

By HECTOR MACPHERSON.

"THE question whether nebulæ are external galaxies hardly any longer needs discussion. It has been answered by the progress of research. No competent thinker with the whole of the available evidence before him can now, it is safe to say, maintain any single nebula to be a star-system of co-ordinate rank with the Milky Way." These words of the late Miss Agnes Clerke, that most careful and impartial writer, appeared in the second edition of 'The System of the Stars,' published in 1905. Yet within a decade the whole question had been reopened, not only in regard to certain nebulæ but in regard to globular star-clusters as well.

Perhaps, indeed, nothing in recent astronomical history has been quite so remarkable as the revival—in a modified form, it is true—of the old theory of "island universes," which formed so important a part of Herschel's first hypothesis of the construction of the universe, and figures so prominently in the textbooks and popular handbooks of astronomy in the middle of the last century. The idea, of course, did not originate with Herschel. Thomas Wright of Durham, in 1750, in his 'Theory of the Universe,' said of the "many cloudy spots just perceivable by us"—"these in all likelihood may be external creation, bordering upon the known one, too remote for even our telescopes to reach." Wright's views were in the main adopted by Kant in 1755 and by Lambert in 1761. When, therefore, Herschel in his first theory of the "construction of the heavens" spoke of the nebulæ and clusters as "island universes," he but extended and developed an idea familiar to readers of the works of Wright, Kant, and Lambert. Herschel's theory of island universes was the natural corollary of his "disc-theory." In 1785, when that famous hypothesis had just been propounded, Herschel, speaking of his discoveries of nebulæ, remarked that he had discovered "fifteen hundred whole sidereal systems, some of which might well outvie our Milky Way in

*From "The Observatory", September, 1919.

grandeur." This view—bold and picturesque—appealed to the imagination of popular writers on astronomy and held a place in astromomical literature for many years. After Herschel abandoned the disc-theory and developed his hypothesis of the gaseous nature of many nebulæ, the conception of "island universes" dropped out of the central place in his thoughts which it had formerly held; although as late as 1818 he gave expression to the view that some of the nebulæ—not obviously gaseous—which he called "ambiguous objects" were "clusters of stars in disguise, on account of their being so deeply immersed in space that none of the gauging powers of our telescopes have hitherto been able to reach them." Obviously at the close of his career, Herschel still regarded some at least of the fainter nebulæ as "island universes."

The island universe theory revived considerably as a result of the resolution of many nebulæ and the supposed resolution of others in the middle of the nineteenth century by the great Rosse reflector and the large refractors of Harvard and Pulkova. But the pendulum of astronomical opinion swung violently in the opposite direction when the gaseous nature of the planetary and irregular nebulæ was demonstrated by Huggins and the early spectroscopists; and by the close of the century the vast majority of astronomers were prepared to subscribe to the dictum of Proctor, in 1872, that "all the nebulæ hitherto discovered, whether gaseous or stellar, irregular, planetary, ring-formed, or elliptic, exist within the limits of the sidereal system. They all form part and parcel of that wonderful system whose nearer and brighter parts constitute the glories of our nocturnal heavens. Proctor, it is true, did not hold this view rigidly. For instance, in 1869 he considered it "not improbable that the spiral nebulæ are galaxies resembling our own," and in 1886 he was favourably disposed towards the view that the nubeculæ might be outlying systems. "If," he said, "the nubeculæ are not external galaxies resembling our own, they present at any rate all the appearances which such galaxies would present from a very distant standpoint." But these were mere suggestions on Proctor's part; he never regarded them as serious hypotheses. At the beginning of the present century the chief students of the structure of the universe, such

as Gore and Newcomb, held strongly to the belief in a limited universe, comprising all the stars and nebulæ within the reach of telescopic vision. "That collection of stars which we call the universe is limited in extent," wrote Newcomb in 1901. "This," he added, "does not preclude the possibility that far outside of our universe there may be other collections of stars of which we know nothing."

The reopening of the question during the last decade has been due to certain more or less reliable measures and estimates of the distances of spiral nebulæ and star-clusters, combined with the results of spectroscopic observations and theoretical considerations. In November 1911 Prof. F. W. Very, the American astronomer, contributed to *Astronomische Nachrichten* an important article "On the White Nebular Galaxies," in which, after an elaborate discussion of the dimensions of the Milky Way, he concluded that the faint white nebulæ were island universes—the smallest and faintest being distant about a million light-years. In 1912 Dr. V. M. Slipher commenced at the Lowell Observatory his remarkable series of measurements of the radial velocities of the spiral nebulæ. Grave doubts had already been thrown on their supposed gaseous nature by the evidence of the spectroscope. The spectrum of the typical spiral is continuous. Slipher's investigations have shown that "the average velocity of the spirals is about twenty-five times the average stellar velocity." This fact differentiates them sharply from the ordinary irregular nebulæ; so does the peculiarity of their distribution. Unlike the planetary and extended nebulæ, they avoid the galactic regions altogether, being most numerous near the galactic poles. These remarkable characteristics seemed to emphasize the non-nebular, extra-galactic nature of the spirals, and accordingly the island universe theory—of the spirals—began to find a measure of support among the leading astronomers.

Remarkable progress has been made in recent years in the study of stellar clusters. In 1913 Prof. Hertzsprung estimated the distance of the Nubecula Minor, from a study of its Cepheid variables, at 10,000 parsecs, corresponding to about 30,000 light-years. About the same time Dr. Harlow Shapley began at Mount Wilson his classical researches on clusters of stars which have

been published in his series of papers on "Studies based on the Colours and Magnitudes in Stellar Clusters." The first cluster exhaustively studied was that in Hercules (M 13) and in his paper on "Thirteen Hundred Stars in the Hercules Cluster," dated August 1915, Shapley computed its distance from "considerations of its variable stars, its fragmentary luminosity-curves, and the average apparent brightness of certain colour-groups." The estimate reached, 100,000 light-years, was confirmed by the researches of Hertzsprung. Adopting this estimate as approximately true, Shapley estimated the diameter of the cluster at 1100 light-years. The provisional conclusion reached was that "the peculiar distribution of globular clusters and their great distances from the Earth show that they do not form a part of the galactic stellar system. Each globular cluster is a complete and separate system by itself." Of course, these researches, while they indicate a much greater distance for M 13 and for globular clusters in general than was previously accepted, also indicated them to be miniatures of the stellar universe rather than coequal systems. In a further paper by Dr. Shapley and Mr. Pease, published in 1917, the analogy between our Galaxy and the globular clusters was still further emphasized by the detection of "axes of symmetry" representing "the lines of intersection with the celestial sphere of the central plane of a system analogous in form to our own Galaxy."

Shapley's later researches have resulted in the determination of the distances of a number of other clusters. He finds the most distant cluster at present known to be N.G.C. 7006 at a distance of 67,000 parsecs, equal to 220,000 light-years; while the nearest is 21,000 light-years distant. These results are in harmony with the island universe hypothesis so long as we accept modest estimates of the dimensions of our own galactic system, such as that of Newcomb—about 6000 light-years. But Shapley, from his study of the Cepheid variables, now finds the most distant of these objects to be 20,000 light-years from the Sun. Our own galactic system then is considerably larger than the earlier estimates allowed. In his paper of April 1918, "Remarks on the Arrangement of the Sidereal Universe," Dr. Shapley has modified his original theory that the clusters are separate galaxies compared to our own. "So long as the diameter of the galactic system was

thought to be only a thousand light-years or so we had a fairly plausible case for the 'island universe' hypothesis," but "any external universe must now be compared with a galactic system probably more than three hundred thousand light-years in diameter."

Can we then speak of star-clusters as island universes? If we mean by island universes, systems independent of and coequal in dimensions with our galactic system, the answer is in the negative. Indeed, Prof Perrine pointed out over two years ago that "if the distribution of the globular clusters is in fact so closely related to the Galaxy (our stellar system), it seems improbable that these objects are strictly intergalactic." Perrine drew attention to the fact that "according to the N.G.C. there are also two groups of globular clusters in the regions of the two nubeculæ," adding that, if this be confirmed, "additional weight would be given to the probability that these bodies are dependents rather than primary systems." Apparently, they are distinctive subordinate systems. In Dr. Crommelin's view, they may be regarded as outer appendages of the galaxy; and recently Dr. Shapley suggestively wrote "Perhaps we should distinguish 'islands' and 'continents'; for in a certain sense I should now consider globular clusters and spirals as small islands in space." The globular clusters seem to be, at the present stage of cosmical history, self-governing units—outlying portions of the galactic domain, but not external and independent galaxies.

It is perhaps scarcely legitimate at present to speak of clusters and spirals as more or less similar objects. Recent research has brought out several important points of difference between them. The radial velocities of clusters, so far as is known, are predominantly negative: that is to say, they are approaching the Sun, while the spirals as a class—"apparently regardless of the gravitational attraction of the galactic system," as Dr. Shapley points out —are receding with great velocities*. This, combined with the

*According to De Sitter (*M. N.* lxxviii. p. 26, "Einstein's Theory of Gravitation") these high radial velocities are spurious, if Einstein's theory is true. The displacement of the spectral lines would be due not to the motion of the spirals, but to their great distance, a conclusion which harmonises with the "island universe" theory.

known difference in distribution of the two classes of objects, indicates a fundamental difference between them. Accordingly, Shapley distinguishes them as two types of sidereal organization in extra-galactic space—the evidence suggesting that the "galactic system now moves as a whole through space, driving the spiral nebulæ before it, and absorbing and disintegrating isolated stellar groups." This would suggest that gravitation prevails up to the distance of the clusters, and that repulsion is the ruling power so far as the spirals are concerned. In this connection a recent paper by Prof. Very on "The Luminiferous Ether" is suggestive. The paper is, of course, largely speculative, and is chiefly an exposition of Very's views on the atom, the ether, and gravitation; but his theoretical conclusions are certainly in accord with recent spectroscopic work on spirals. After pointing out the relative "sparsity of stellar material" in the galactic system, he emphasizes the comparative crowding of the spirals. "Since these objects have velocities of upwards of 1000 km. per sec., frequent collisions are inevitable unless there are mutual repulsions which develop upon arriving at too close proximity. This result might, however, be produced in another way, provided gravitational attraction, by which we assume the stellar movements are given, is not universal, but is limited to definite volumes around each galactic centre, within which gravity is controlled by definitely limited currents of the aura." One difficulty in this hypothesis is that the distances calculated by Very for some of these spirals—up to 80,000 light-years—are less than Shapley's estimated distances of the farthest clusters, which are obviously controlled by gravitation. If, however, we assume greater distances for the spirals, this difficulty is removed and Very's theory is strengthened.

Greater distances have, indeed, been computed. Discussions of the temporary stars in the Andromeda nebula, which has been called the nearest of the spirals and conforms with the novæ in the galactic system, have led to an estimated distance of 1,000,000 light-years and a diameter of 50,000 light-years for that nebula. The Messrs. Lindemann, in their recent preliminary application of photo-electric photometry to astronomy, have reached a somewhat similar estimate of the distance of the same nebula—350,000

parsecs; and they maintain that there is "nothing inconsistent in regarding this nebula as a galaxy very similar to our own."

The problem of the spirals is at present far from solution; and judgment on their exact status must be suspended until we are in possession of more detailed knowledge. Meanwhile, it would seem that there are three possible theories:—(1) That these spirals are within the galactic system and are not actually stellar, but nebulous; (2) that they are appendages of the galactic system, of the same order of distance as the globular clusters; and (3) that they are actually external galaxies, coequal with the stellar system. The first theory seems highly improbable, in view of the obvious differences between spiral and other nebulæ showing gaseous spectra. Dr. Shapley and others are inclined towards the second theory—that the spirals are about as distant as globular clusters. Why, then, it may be asked, are they irresolvable in the most powerful telescopes? It has been computed that their most luminous stars must be fainter than the 21st magnitude. This indicates either that (i) they are composed of dwarf stars—an idea by no means improbable,— or (ii) that they are far beyond the clusters, in which case they must be true external universes. For this view there is also considerable support. At present we may look on the spirals as either independent galaxies or miniatures of the galactic system composed of dwarf stars. The spiral form is itself suggestive. "The two arms of the spiral," Prof. Eddington remarks, "have an interesting meaning for us in connection with stellar movements. . . . . The two star streams" (in our galactic system) "and the double-branched spiral arise from the same cause."

In the present state of our knowledge we may compare our galactic system to a continent surrounded on all sides by the ocean of space, and the globular cluster to small islands lying at varying distances from its shores; while the spiral nebulæ would appear to be either smaller islands, or else independent "continents" shining dimly out of Immensity.

THE OBSERVATION OF METEORS AND COMPUTATION OF THEIR REAL PATHS.

By W. F. Denning.

THIS work was continued at Bristol in 1918. Very efficient aid in the collection of data was rendered by the members of the meteoric section of the British Astronomical Association among whom the most successful observers were Mrs. Fiammetta Wilson of Totteridge, Miss A. Grace Cook of Stowmarket, and Mr. S. B. Mattey of Longfield, Kent.

The total number of real paths of fireballs and shooting stars computed here during the years 1886 to 1918 inclusive was 1,065, and three catalogues containing 788 of these were published in the monthly notices of the R.A.S. as follows: 107 meteors in 10 years, 1886-96, January, 1897; 429 meteors in 15 years, 1897-1911, March, 1912; 252 meteros in 4 years, 1912-15, January, 1916.

To the end of 1918 the real paths of 277 additional objects had been investigated and details of these have been published in the Journal of the British Astronomical Association.

The annual number of meteors of which sufficiently ample data were obtained for satisfactory computation was as follows during the last 9 years: 1910, 24 meteors; 1911, 40 meteors; 1912, 16 meteors; 1913, 44 meteors; 1914, 104 meteors; 1915, 86 meteors; 1916, 75 meteors; 1917, 97 meteors; 1918, 105 meteors.

The results have, therefore, been far more abundant in recent years than formerly and this is due in a very great measure to the untiring and very successful labours of Mrs. Wilson in the field of observation.

The long-duration of certain radiants from the same apparent points in the sky and the displacement from night to night of various periodical showers such as the Perseids and Lyrids have been well corroborated by the results obtained. It is believed that when full investigations have been made that important evidence will be forthcoming as to the duration and radiation of meteoric streams generally.

The following fireballs were satisfactorily observed and their real paths computed in 1918:

REAL PATHS OF FIREBALLS SEEN IN 1918.

Date 1918	G.M.T. h m	Mag.	Height at First Miles	Height at End Miles	Length of Path Miles	Velocity per Second Miles	Radiant	Observers
Feb. 16	7 39	1−♃	75	41	49	32	150°+39°	AGC, WFD
Mar. 21	8 26	3×♃	60	41	58	16	350+51	AGC & others
May 2	9 25	♃−♀	64	33	70	14	110+25	SBM & others
June 11	10 54	3×♀ 8+♃	65	27	76	25	166+31	DRS, BB
June 30	9 18	=☽	75	18	65	19	232+31	8 observers
July 8	10 34	♃−2×♃	69	32	50	50	300+24	FW, BB
July 31	10 51	1−♀	73	54	34	34	36+58	FW, AGC
Aug. 9	10 35	♀−3×♀	86	46	73	40	42+59	FW, WFD
Aug. 10	10 3	♀−5×♀	79	55	55	30	42+57	FW, WFD
Aug. 12	8 56	♀−½☽	77	52	65	43	48+59	A. King & another
Aug. 12	9 51	1−♃	81	49	60	40	46+57	AGC, BB
Aug. 12	11 27	1−♀	81	45	60	40	49+58	FW, WFD & others
Aug. 12	11 30	♃−♀	78	50	45	45	51+59	AGC, WFD
Aug. 12	11 32	1−♃	83	53	47	42	45+59	FW, WFD
Aug. 13	9 34	1−♃	62	53	33	25	323−15	FW, AGC, WFD, BB
Sep. 2	10 11	1−♀	73	41	37	21	264+63	FW, WFD
Sep. 7	10 13	♀−4×♀	64	29	170	14	324−25	FW, SBM
Sep. 10	9 6	2−♃	67	67	60	34	90+34	FW, AGC
Sep. 11	8 34	♃−♀	89	48	35	24 or	330+72 320+76	FW, AGC
Oct. 4	8 43	♀−♀	46	32	44	11	13−10	FW, WFD
Oct. 16	5 50	♀	80	52	61	..	162+59	Several observers
Nov. 3	10 7	♃	74	62	57	..	152+41	3 observers
Dec. 6	9 36	½☽	67	24	67	22	133+68	2 observers

Abbreviations—FW = Mrs. Fiammetta Wilson; AGC = Miss A. Grace Cook; SBM = Mr. S. B. Malley; BB = Mr. Basil Brown; DRS = Mr. D. R. Springall; WFD = Mr. W. F. Denning.

NOMOGRAM SHOWING DURATION OF SUNLIGHT.

By W. H. HERBERT.

THE climate of Canada necessarily extends through a considerable range as the country covers a large angle in latitude. One of the chief elements of a climate is the daily duration of sunshine during the year for different latitudes; this duration being a function of the latitude of the place and the declination of the sun.

Due to the great daily duration of sunshine in the northern latitudes during the summer season, agriculture is possible very much farther north than would otherwise be the case. It is a fact not generally understood that the northern latitudes receive during the summer much more sunshine than do the southern latitudes. While exactly the reverse is true during the winter; nevertheless the summer conditions are so favorable that successful agriculture is rendered easily possible over large territories lying in the north.

One means of comparison, therefore, between a southern area and a northern area is on the basis of the total duration of sunshine during the agricultural or crop-growing season, and this may be obtained by summing the daily duration over the selected interval.

The duration of sunlight during any day is evidently the interval between sunrise and sunset, or twice the hour angle at sunrise or sunset, which is given by the equation:

$\cos t = \sin h \sec L \sec d - \tan L \tan d$, where

t = hour angle of sun,

h = altitude of sun,

d = declination of sun,

L = latitude of place.

If in this formula the value of d is taken from an ephemeris, the result will be the geocentric hourangle for the geocentric horizon. In the case of the sun, this differs from the geocentric hour-angle when the body is apparently on the sensible horizon because of refraction and parallax. Also, the question is concerned with the upper limb instead of the centre of the sun.

The upper limb of the sun is really 34 minutes of arc below the horizon when it appears to be exactly on the horizon. This is due to refraction. Also the centre of the sun is 16 minutes of arc below the upper limb. The centre is therefore 50 minutes of arc below the sensible horizon. If the parallax be neglected, the altitude may be taken as -50 minutes, and sin h as -0.0145, and the equation becomes,

$$\cos t = -(0.0145 \sec L \sec d + \tan L \tan d).$$

Double this hourangle will give the duration of sunlight.

This equation is not easy of application by the man in the street, though the information is of some considerable value in everyday affairs, especially for settlers contemplating locating in some northern area such as the Peace River District.

It is quite obvious that tables could be constructed for presenting this information; but it is also obvious they would necessarily be of considerable size and involve much labour in compilation. Also, tables of this nature are not readily understood and appreciated by the people most needing this information.

Owing to inquiries concerning this subject, it was decided to evolve some graphic method of solution, and the parallel-scale nomogram naturally suggested itself as the most suitable.

In order to apply the equation to a parallel-scale nomogram it was first necessary to reduce it to the linear form, which was done as follows:

The first term, 0.0145 sec L sec d, can evidently be changed into the form 0.0145 k tan L sec d, where k is a constant, for latitudes 42° to 60° without involving any appreciable error. For determining the value of k, it is sufficient to write one equation of the form:

$$k \tan L = \sec L,$$

for each degree of latitude between 42° and 60°, both inclusive. These equations can then be reduced to the normal form, which gives k a value of 1.26.

The expression then becomes

$$\cos t = -(0.0183 \sec d + \tan d) \tan L.$$

By trial, the duration of sunlight is found to lie between 5 and 19 hours for the conditions considered. These values are plotted on the left hand vertical scale, or u scale, using the cosine function, and a modulus l_1 as a unit of length.

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DEPARTMENT OF THE INTERIOR
CANADA

HON. ARTHUR MEIGHEN, MINISTER
W. W. CORY, DEPUTY MINISTER

TOPOGRAPHICAL SURVEYS BRANCH

E. DEVILLE, L.L.D.
Surveyor General

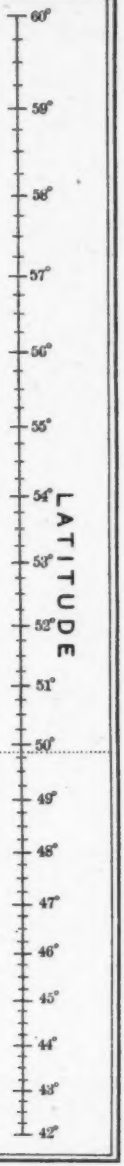
NOMOGRAM

Showing

DURATION OF SUNLIGHT

For every day in the year

all places in Canada between latitudes 42° N. and 60° N.



The latitude is plotted on the right hand vertical scale, or v scale, using the tangent function, and a modulus l_2 as a unit of length.

The equation then becomes

$$\frac{u}{l_1}+(0.0183 \sec d+ \tan d)\frac{v}{l_2}=0;$$

whence the equation of the third scale, the scale of d, becomes

$$x=A\frac{(0.0183 \sec d+\tan d)\ l_1-l_2}{(0.0183 \sec d+\tan d)\ l_1+l_2}$$

$y=o$, where A is the half distance separating the u and v scales.

It is seen that the d scale is a straight line.

Instead of plotting values of the declination, however, the corresponding Greenwich mean noon was used as being more convenient. While the data is shown for 1918, it is equally applicable to all years, the variation from year to year being negligible within the limits of the nomogram.

To find the duration of sunlight for any day in the year, for any place in Canada between latitudes 42° N and 60° N, lay a straight-edge across the nomogram between the latitude on the right hand scale and the date on the inclined scale, and read off the duration of sunlight on the left hand vertical scale.

Example—Latitude of Winnipeg, 49° 52′; date, April 21; duration of sunlight, 14.10 hours. Solution is shown by dotted line, but no actual line is necessary.

If the total hours of sunshine be integrated for an agricultural season of four and a half months—April 15th to August 31, the following results are obtained.

Total hours of sunshine.	*Latitude.*
2100	48.7
2150	51.7
2200	54.1
2250	56.1
2300	58.2
2350	59.8

TOPOGRAPHICAL SURVEYS,
DEPARTMENT OF THE INTERIOR,
OTTAWA, August, 1919.

NOTES FROM THE DOMINION OBSERVATORY, VICTORIA, B.C.

FOURTH LIST OF SPECTROSCOPIC BINARIES.

By J. S. Plaskett, W. E. Harper, R. K. Young.

THE following table contains a list of 25 binaries discovered in the course of the radial velocity work of this observatory. The first list of 12 binaries was published in the November, 1918, the second list of 18 binaries in the February, 1919, and the third list of 20 binaries in the April, 1919, issues of The Journal, which, with this list, makes 75 to date.

As in the previous lists, the serial numbers are continued and the binaries are arranged in order of right ascension for convenience of reference. Notes in regard to the character of the spectrum and other remarks which are too long to be incorporated in the table, are given below the latter, the purpose being to make the data about each sufficiently complete to enable observers desiring to work at any of these binaries to decide on the character of the spectrum and its suitability for obtaining an orbit without making test plates.

For several stars measured here, other than the 75 in these lists, there is probably a variation in the velocity but the observed range is so little greater than that likely to occur owing to error of determination as to make their binary character uncertain. As in such cases it would be impossible to determine orbits, and as, for radial velocity statistics, only the velocity of the centre of gravity of the system is required, this can be obtained with sufficient accuracy by securing say 10 or 12 plates of such stars over an interval long enough to cover more than one revolution of the system and the question as to whether they are binary or not is then not of so much moment.

In the table, column 1 gives the serial number of the binary. Column 2 gives the number of the star in Boss's Catalogue and in

No.	Star R.A. 1900 Dec. 1900	Type Mag.	Date	Julian Day	Radial Velocity	Quality.	Discoverer.
51	Boss 866		Oct. 29/18	2,421,896.906	−23.6	Good	P
	H.R. 1158	A3	Dec. 22	1,950.769	−34.1	Fair	
	03h 40. m8	5. 96	Jan. 19/19	1,978. 696	− 4.5	Good	
	+63° 00′		" 19	1,978. 704	+ 4.0	"	
52	Boss 1018		Dec. 20/18	2,421,948. 799	+12. 8	Good	Y
	H.R. 1368	A3	" 30	1,958,744	+47. 4	"	
	04h 16m . 4	5. 8	Jan. 31/19	1,990.657	+58. 9	"	
	+13° 50′						
53	Boss 1051		Oct. 30/18	2,421,897.916	+48. 8	Good	Y
	H.R. 1422	Fo	Dec. 16	1,944.808	+23. 1	"	
	04h 24m. 4	5. 7	Jan. 31/19	1,990.689	+34. 8	"	
	+15° 25′						
54	Boss 1058		Jan. 30/19	2,421,989.671	+53. 2	Fair	P
	H.R. 1432	Fo	Feb. 2	1,992.622	+40. 4	Good	
	04h 26m. 2	6. 04	" 11	2,001.678	+42. 5	"	
	+15° 38′		" 23	2,013.610	+39. 0	"	
			Mar. 20	2,038.640	+27. 6	"	
55	Boss 1068		Nov. 26/18	2,421,924.891	+14. 3	Fair	P
	H.R. 1445	B9	Dec. 10	1,938.828	+ 6. 4	Good	
	04h 28m. 4	5. 70	" 21	1,949.840	+ 3. 4	"	
	+28° 46′		Jan. 19/19	1,978.771	+ 8. 1	"	
			Mar. 8	2,026.636	+18. 8	"	
			" 18	2,036.649	+22. 0	"	
56	Boss 1122		Dec. 10/18	2,421,938.852	+32. 1	Good	P
	H.R. 1519	Ao	" 14	1,942.872	+28. 8	"	
	04h 40m. 5	5. 43	" 29	1,957.824	+45. 8	"	
	+11° 31′		Jan. 30/19	1,989.690	+46. 2	"	
57	Boss 1244		Dec. 14/18	2,421,942.905	+16. 9	Good	P
	H.R. 1706	A2	" 29	1,957.856	+16. 9	"	
	05h 08m . 8	5. 14	Jan. 7/19	1,966.822	- 15. 7	"	
	+32° 35′		" 30	1,989.698	−25. 7	"	
58	Boss 1276		Feb. 4/19	2,421,994.682	− 0. 2	Good	P
	H.R. 1751	Ao	" 23	2,013.665	+17. 5	"	
	05h 14m. 9	5. 25	Mar. 2	2,020.625	− 0. 3	"	
	+57° 27′		" 20	2,038.696	+12. 9	"	
59	Boss 1410		Jan. 30/19	2,421,989.723	−15. 9	Good	P
	H.R. 1969	A2	Feb. 2	1,992.647	+14. 5	"	
	05h 38m . 1	6. 06	" 2	1,992.656	+16. 5	"	
	+56° 05′		" 11	2,001.720	+55. 4	"	
			" 23	2,013.694	+54. 5	"	
			" 23	2,013.708	+28. 1	"	
60	Boss 1452		Dec. 10/18	2,421,938. 924	+21. 0	Good	P
	H.R. 2027	Ao	" 21	1,949.892	+67. 8	"	
	05h 46m . 0	5. 26	Feb. 1/19	1,991.758	+ 6. 2	"	
	+59° 52′		" 2	1,992.683	−76. 4	"	
			" 11	2,001.751	−60. 1	"	
			" 11	2,001.759	−51. 9	"	

No.	Star R.A. 1900 Dec. 1900	Type Mag.	Date.	Julian Day.	Radial Velocity.	Quality.	Discoverer.
61	Boss 1455		Dec. 30/18	2,421,958.827	+ 4.0	Good	Y
	H.R. 2033	B9	Jan. 6/19	1,965.810	− 6.1	"	
	05h 46m .7	5.6	" 10	1,969.831	− 9.1	"	
	+14° 09′		Mar. 24	2,042.633	−12.9	"	
62	Boss 1559		Nov. 4/18	2,421,902.966	+ 7.6	Good	Y
	H.R. 2214	A5	Dec. 16	1,944.885	+38.4	"	
	06h 08m .6	5.8	Jan. 29/19	1,988.746	+39.4	"	
	+17° 57′						
63	Boss 2013		Dec. 20/18	2,421,948.919	+ 6.4	Fair	Y
	H.R. 2950	Ao	Jan. 6/19	1,965.892	+19.0	"	
	07h 34m .8	5.8	" 29	1,988.814	+26.3	Good	
	+5° 28′		" 31	1,990.789	+33.4	"	
			Mar. 21	2,039.647	+ 6.9	"	
			April 7 4	2,056.645	− 2.5	"	
64	Boss 2022		Dec. 29/18	2,421,957.954	−19.0	Good	P
	H.R. 2969	Ao	Mar. 18/19	2,036.720	+25.6	"	
	07h 36m .5	5.28	" 18	2,036.732	+16.8	"	
	+50° 40′		" 23	2,041.698	+17.2	"	
			" 23	2,041.709	+ 5.3	"	
65	Boss 2142		Feb. 11/19	2,422,001.823	+23.0	Good	H
	H.R. 3167	Ao	" 23	2,013.774	+68.8	"	
	08h 00m .2	6.2			- 60.7		
	+43° 34′		March 18	2,036.762	+10.7	Fine	
			April 6	2,055.653	+10.3	"	
			" 6	2,055.668	+ 14.6	"	
66	Boss 2173		Dec. 16/18	2,421,944.962	+27.8	Good	Y
	H.R. 3215	Aop	" 16	1,944.978	+21.8	"	
	08h 06m .9	5.6	" 30	1,958.832	+16.7	"	
	+29° 57′		Mar. 21/19	2,039.693	+ 7.4	"	
67	Boss 2251		Dec. 20/18	2,421,948.941	+15.6	Fair	Y
	H.R. 3329	A5	Jan. 10/19	1,969.888	+ 6.7	Good	
	08h 22m .7	6.1	Feb. 17	2,007.819	+20.0	"	
	+24° 28′		Mar. 24	2,042.696	+ 1.7	"	
68	Boss 2432		Dec. 29/18	2,421,956.995	−12.6	Good	P
	H.R. 3603	F5	Feb. 11/19	2,001.865	+ 7.2	"	
	08h 58m .5	5.59	" 23	2,013.843	+10.6	"	
	+48° 55′		Mar. 18	2,036.795	+12.8	"	
69	Boss 2463		Feb. 5/19	2,421,995.859	−50.6	Fine	Y
	H.R. 3648	F8	Mar. 19	2,037.700	+ 8.2	"	
	09h 06m .4	5.2	April 14	2,063.678	- 6.6	"	
	+61° 50′		" 25	2,074.662	−48.3	"	
70	Boss 3909		Apr. 28/19	2,422,077.823	- 26.	Weak	H
	.....	Ao	May 5	2,084.825	− 3.	Good	
	15h 16m .3	7.4	" 20	2,099.799	−28.	Fair	
	+50° 35′		" 28	2,107.777	− 5.	Poor	
			" 30	2,109.725	+14.	Fair	
			June 9	2,119.748	−22.	"	
			July 7	2,147.748	− 4	Good	

No.	Star R.A. 1900 Dec. 1900	Type Mag.	Date	Julian Day	Radial Velocity	Quality.	Discoverer.
71	Boss 4121		May 20/18	2,421,734.841	−51.3	Good	Y
	H.R. 6034	Ao	June 20	1,765.789	−23.5	"	
	16h 06m .9	5.6	July 23	1,798.703	−41.	Fair	
	+77° 04′		June 4/19	2,114.827	−29.0	Good	
			July 20	2,160.698	−16.1	"	
72	Boss 4507		May 28/19	2,422,107.927	−85.6	Weak	H
	H.R. 6641	Ao	" 31	2,110.808	−86.4	Fine	
	17h 44m .4	6.3	June 9	2,119.891	−28.3	Fair	
	+47° 39′						
73	Boss 4622		July 7/19	2,422,147.816	−83. }	Good	H
	H.R. 6849	Fo	" 14		+66. }		
	18h 13m .0	6.4	" 15	2,154.814	−122. }	Fair	
	+56° 34′				+73. }		
				2,155.832	−110. }	"	
					+108. }		
74	Boss 4869		May 20/18	2,421,734.972	−51.2	Fair	Y
	H.R. 7251	Ao	June 17	1,762.889	−25.3	Poor	
	19h 02m .6	5.3	July 16	1,791.890	−67.6	Fair	
	+53° 14′		Sept. 5	1,842.707	−21.3	Good	
			July 6/19	2,146.837	− 14.7	"	
			" 30	2,170.793	+ 8.	Fair	
			Aug. 10	2,181.741	−15.	"	
			" 22	2,193.683	−31.5	"	
75	Boss 5026		July 21/19	2,422.161.798	−75.1 }	Good	
	H.R. 7484	F5		2,162.797	+26.7 }		H
	19h 36m .4	5.9	" 22	2,163.854	+106.0 }	"	
	+54° 44′				−125.1 }		
			" 23		−18.5	"	

the Revised Harvard Photometry and its Right Ascension and Declination for 1900. Column 3 gives the visual magnitude and spectral type from the Henry Draper Catalogue, the unpublished data being kindly supplied by Professor Pickering. Column 4 gives the date of the observation of each plate. Column 5 gives the Julian day and fraction of a day of the observation. Column 6 gives the measured radial velocity to tenths of a kilometre. Column 7 gives the respective quality of the individual plates as regards suitable exposure and development, but does not give any indication of the character of the lines, which is discussed in the supplementary remarks. The last column gives the discoverer, *P* standing for Plaskett, *H* for Harper, and *Y* for Young. It should be noted in this regard that very efficient assistance in the setting of the telescope and the guiding of the great majority of these spectrograms and indeed the majority of all obtained here, has been given by Mr. T. T. Hutchison the engineer and night assistant.

No. 51. This spectrum of type A3 contains numerous metallic lines in addition to the hydrogen series but all the lines are broad and diffuse and the spectra are not susceptible of accurate measurement.

No. 52. There are many very fine lines in the spectrum of this star, from 16 to 20 being measured. The star is one of the Taurus cluster.

No. 53. The quality of the spectrum for measurement is rather poor. There are numerous lines present which are rather fuzzy and poorly defined. This star belongs to the Taurus cluster.

No. 54. The lines in this Fo spectrum are all broad and it is consequently unsuitable for measurement on the Hartmann Spectro-Comparator. The inter-agreement among the lines is fair, however, and the measures are reliable.

No. 55. The spectrum of type B9 contains narrow and sharp Mg 4481 and K lines. The hydrogen lines are also well measurable but helium and silicon are weak. The measures may be considered as reliable.

No. 56. This spectrum listed A0 is nearer A2 and contains a large number of very sharp metallic lines and the measures are hence accurate.

No. 57. This spectrum type A2 is very similar in character to No. 56 containing numerous narrow sharp metallic lines and the measures are equally reliable.

No. 58. The lines in this A0 spectrum are broad and faint, only 4481, K and the hydrogen lines being usually measurable. The inter-agreement among the lines is fair, however, and the measures probably of fair accuracy.

No. 59. This spectrum A2 is very similar in character to Nos. 51 and 58 and the measures of about the same order of accuracy.

No. 60. The spectrum of type A0 contains in addition to the hydrogen lines and a trace of the silicon pair 4128, 4131, several metallic lines fairly well defined and the measures may be considered fairly reliable.

No. 61. From 6 to 9 lines were measured in these spectra. Calcium K, the hydrogen lines Hδ and Hγ, also λ4233 and 4481. There are traces of many faint metallic lines. All are sharp and narrow. The silicon lines 4128 and 4131 are also present.

No. 62. Numerous lines characteristic of this type of spectrum are present in the spectrum. They are of fair quality only. From 11 to 14 were measured.

No. 63. The calcium line K, the Hydrogen lines Hδ and Hγ and the two lines λ4481 and 4549 were all that were measured in this spectrum. They are fairly well defined and narrow. K, 4481 and 4549 are rather weak for accurate measurement.

No. 64. The lines in this A0 spectrum are all very broad and the plates are hence not susceptible of accurate measurement.

No. 65. The spectrum consists of broad hydrogen lines with sharp magnesium, λ4481 and sharp calcium λ3933. The second plate shows the hydrogen lines apparently complex and the calcium and magnesium decidedly so. The last three velocities must be close to the velocity of the system as the latter two lines are extremely sharp.

No. 66. The lines are of good quality for measurement. The silicon lines 4128, 4131 are strong. The calcium, hydrogen and magnesium and several iron lines are also well defined.

No. 67. From 8 to 14 lines were measured in the spectra of this star. They are of poor quality. There seems little doubt of the

reality of the variation but the computation of an orbit would prove a difficult task if the range is not larger than as indicated.

No. 68. The lines in this F5 spectrum are broad and though numerous, few are well enough defined for accurate measurements. The measures are fairly reliable.

No. 69. This is a fine spectrum for accurate measurement, being very similar to Procyon. The measures were made on the Hartmann engine with Procyon as a standard.

No. 70. In addition to the hydrogen lines the magnesium λ4481 and calcium λ3933 are fairly sharp and numerous metallic lines also appear. On the best plates 10 or 12 lines were measured, on the weak ones only 3 or 4, but there seems no doubt of a real variation in velocity.

No. 71. The calcium line K, λ4481 and 4549 together with the two hydrogen lines Hδ and Hγ were all that were measured in these spectra. The lines are not of very good quality for accurate measurement.

No. 72. The hydrogen lines are quite well defined in this star which has in addition numerous metallic lines found in this type, from 12 to 20 of which were measured on each plate. The orbit of this star has been completed.

No. 73. The first plate showed definite double lines of the numerous metallic ones found in spectra of this type though none of them are very sharp.

No. 74. This is a rather difficult spectrum to measure. The calcium line K and λ4481 together with the hydrogen lines are present. They are rather wide and diffuse and often suggest duplicity.

No. 75. Quite similar to Boss 4622 except that the lines are better defined. The star is under investigation here.

DOMINION OBSERVATORY,
VICTORIA,
Sept. 6, 1919.

BOOK REVIEWS

The Whys and Wherefores of Navigation. By Gershom Bradford, 206 pages. N.Y., Van Nostrand, 1919. Price $2.00.

So many standard works have been published on the art of navigation that it would seem that little room is left in the literature of the subject for a new book. That there is room, however, is shown by the fact that a second revised and enlarged edition of the work before us has been called for.

The opening chapter is devoted to dead-reckoning; then follow chapters on astronomical subjects: nautical astronomy; declination and right ascension; time; corrections for observed altitudes; latitude; azimuths and amplitudes; and longitude; each of which is treated in a lucid and informal style. A long chapter then follows on Sumner lines and the new navigation, giving a clear account of the development of the methods that have been used for determining the position of a ship by means of lines of position, including the St. Hilaire method, their most recent development. Short chapters on charts and piloting, and an appendix giving a number of problems occurring in navigation, with their answers, bring the book to a close.

The aim of the book is to serve either as an introduction to the subject for those beginning its study, or as an aid to those who have practised the art of navigation so long that they have lost sight of the principles upon which their practice rests. Both classes of readers will find the subject treated in an interesting and attractive style; and the book may well be turned to in order to clear up difficulties met with in more formal treatises.

L. B. STEWART.

The Adolfo Stahl Lectures in Astronomy. Delivered in San Francisco in 1916-17 and 1917-18 under the auspices of the Astronomical Society of the Pacific. 257 pages. San Francisco, 1919. Price $2.75.

The twelve lectures in this volume are: The Solar System, What we Know about Comets, by W. W. Campbell; A Total Eclipse of the Sun, The Moon, News from the Stars, by R. G. Aitken; The Nebulae, Astronomical Discovery, by H. D. Curtis; Important Epochs in the Development of Astronomy, by R. T. Crawford; Our nearest Star the Sun, by C. E. St. John; Recent Progress in the Study of the Motion of Bodies in the Solar System, by A. O. Leuschner; The Brightness of the Stars, their Distribution, Colours and Motions, by F. H. Seares; The 100-inch Reflecting Telescope, Mt. Wilson.

The authors are high authorities in the subjects they discuss and the latest information is given by them in clear and non-technical language. In addition there are 53 fine plates from modern photographs. The book would be improved by an index.

C. A. CHANT.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada August, 1919.

Temperature—In British Columbia the temperature was average or a little below in the north and west parts, and above elsewhere; in the Western Provinces everywhere above; also in Ontario, except in the northeast portion; and average or below in Quebec and the Maritime Provinces. The chief positive departures were 5° at Prince Albert and Calgary, and 4° at Medicine Hat, Swift Current and Port Arthur, whereas the largest negative departures were 3° at Yarmouth and Halifax, and 2° at St. John and Sydney.

Precipitation—The rainfall over the Dominion was very unevenly distributed. In British Columbia it was for the most part very light; in the Western Provinces it varied, some sections recording over three inches, while others had less than one inch. In Ontario it ranged from less than two inches in some places to over six in others, this was especially noticeable in the Peninsula, and from the Nipissing district northward; Cochrane recorded over six inches, an excessive amount for that place. In Quebec the fall was from a little over one inch to about four inches; while in the Maritime Provinces it ranged from less than two inches, very locally, to over eight inches in some districts. The great discrepancies in the amounts of rain over given areas were largely attributable, no doubt, to heavy local thunderstorms, which were frequently recorded.

TEMPERATURES FOR AUGUST 1919

STATION	AUGUST		STATION	AUGUST	
	Highest	Lowest		Highest	Lowest
Yukon			Kenora	85	45
Dawson	82	32	Kinmount	87	37
British Columbia			Kingston	84	46
Atlin	74	34	Kitchener	91	42
Agassiz	86	46	London	90	42
Barkerville	74	32	Lucknow	84	37
Kamloops	96	46	Markdale	89	44
New Westminster	86	50	North Gower	89	35
Prince Rupert	77	44	Oshawa	89	46
Vancouver	80	47	Ottawa	90	43
Victoria	80	48	Paris	93	44
Western Provinces			Parry Sound	94	42
Battleford	91	42	Peterborough	87	43
Calgary	92	41	Port Arthur	82	39
Edmonton	87	35	Port Dover	88	45
Medicine Hat	95	41	Port Stanley	86	46
Minnedosa	98	34	Queensborough	87	37
Moosejaw	97	38	Ronville	84	37
Oakbank	93	34	Southampton	85	45
Portage la Prairie	90	38	Stonecliffe	90	28
Prince Albert	92	40	Stoney Creek	95	45
Qu'Appelle	93	39	Toronto	92	48
Regina	95	18	Uxbridge	87	40
Saskatoon	92	19	Wallaceburg	90	45
Souris	97	37	Welland	89	47
Swift Current	92	40	White River	87	30
Winnipeg	94	36	*Quebec*		
Ontario			Brome	82	35
Agincourt	90	45	Father Point	79	43
Bancroft	82	36	Montreal	84	48
Barrie	89	44	Quebec	78	44
Beatrice	87	34	Sherbrooke	84	43
Bloomfield	84	46	*Maritime Provinces*		
Brantford	92	41	Charlottetown	80	44
Chapleau	92	36	Chatham	86	42
Chatham	93	45	Fredericton	82	39
Clinton	86	39	Halifax	78	44
Cottam	90	40	Moncton	80	43
Georgetown	89	46	St. John	78	47
Gravenhurst	87	41	Sussex	77	42
Grimsby	93	48	Sydney	80	44
Guelph	92	42	Yarmouth	76	44
Haliburton	90	35			
Huntsville	87	35			

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH.

P.T.—Preliminary Tremors. S.—Secondary Waves. L.—Large Waves. A. C.—Aif Cureets Time is Greenwich Mean Civil Time; it is to be given in hours, minutes and decimals of minutes 0 or 24 h—midnight.

TORONTO

Director, SIR FREDERIC STUPART, F.R.S.C.

No.	Date 1919	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks.
		h m	h m	h m	h m	h m	mm.	
2031	Aug. 18			5?31.4	5 31.9	5 35.0	0.2	Doubtful as to being Seismic.
2032	" 18			17?25.4) 17 31.5 ∫	17?33.7		0.2	Early phases lost; attending inst.
2033	" 24			5 15.2		5 18.8	0.1	
2034	" 24			5?29.3	5 29.6	6 05.6	0.2	Last phase gradual thickening.
2035	" 24			12 45.9) 12 58.9 ∫			0.05	
2036	" 27			5 59.8) 6 23.3 ∫	6 34.5	?	0.3	
2037	" 29	5?58.7		6 16.3) 6 57.0 ∫	7 09.5		2.3	Possibly 2 eq. overlapping. Small micros make interpretation difficult.
	" 29	Micros	at 14 34	33 when o	ther stat	ion recor	ded qu	ake.
2038	" 29			14?36.2			0.1	Micros going on.
2039	" 31			0 39.4			0.1	Micros going on.
2040	" 31		17?51.6	18 20.4) 18 21.5 ∫	18 29.2		2.4	Micros going on.

Period of boom 18 seconds. Pillar inclination 1 mm = 0.45."

VICTORIA, B.C.

Superintendent, F. NAPIER DENISON.

No.	Date 1919	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks.
		h m s	h m s	h m s	h m s	h m s	mm.	
2029	Aug. 18				17 17 06	18 07 46	0.3	
2030	" 24				5 16 30	5 47 30	0.3	
2031	" 24				12 43 40	12 49 00	0.1	
2032	" 27	5 42 19	5 46 45	?	6 08 24	6 56 05	0.9	
2033	" 29	6 02 03	6?08 27	6 12 00	6 12 23		0.7	Phases well defined.
2034	" 29	?		6 34 30	6 42 22	8 30 34	1.5	Phases well defined.
2035	" 29	14 34 33			14 40 27	14 46 21	0.05	
2036	" 31	0 29 12		0 34 36	0 37 32	0 45 25	0.5	
2037	" 31	17 27 48	17 33 42	17 43 32	18 12 34	20 13 03	0.5	

Period of boom 18 seconds. Pillar inclination 1mm = 0". 54.

Magnetic Disturbances.
June, July and August, 1919.

The principal magnetic storms recorded at Agincourt and Meanook Observatories during June, July and August, 1919, are as follows:

75th Mean Time.						Range.			
						Agincourt.			Meanook.
Beginning			Ending			H	Z	D	D
	h	m		h	m	γ	γ	′	′
July	17	9 ..	July 18	9	..	145	329	47.0	122.3
"	22	1 ..	" 23	12	..	129	352	45.1	114.4
Aug.	11	1 57	Aug. 12	14	..	930*	980*	224.0*	236.0*
"	18	15 ..	" 20	22	..	261	204	73.5	183.5
"	28	7 58	" 29	7	..	99	109	45.5	61.3

*Estimated values. Light passed beyond limits of recording apparatus.

The magnetic storm of August 11 and 12 was the most pronounced recorded as yet this year and was synchronous with the interruption of the telegraph service over the greater part of North America. On the 10th of August the magnets were particularly quiet, but shortly after midnight a large westerly bay was recorded at Agincourt in D and a large serrated easterly bay at Meanook. The Agincourt Z decreased considerably and the H slightly. At 1h 57m on August 11 at Agincourt a sudden increase in H and Z and decrease in West Declination was followed immediately by large reverse movements and the storm was in full swing. At Meanook sharp vibrations occurred a few minutes earlier than at Agincourt. From the commencement up to 5h the magnets were most violently disturbed, a second increase in intensity occurred from 9h to 12h, a third near 21h and a fourth and last near 3h of August 12, after which the storm gradually subsided. During the intervening periods the storm was still very active, the oscillations having a period of from 2 to 3 minutes and amplitudes of from 40 γ to 200 γ in H, a little less in Z, and from 10′ to 40′ in D at Agincourt and a little greater in D at Meanook.

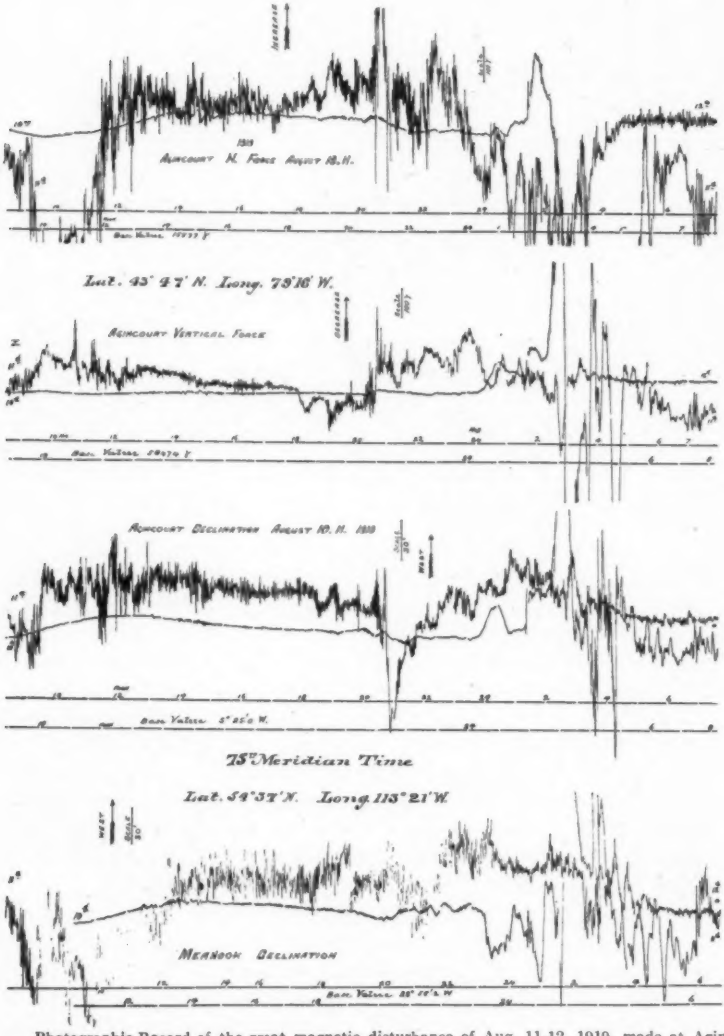
Following the method, outlined in a paper on "The Magnetic Storm of August 26-27, 1916" in the Journal for January, 1917, the Resultant Impressed Force was computed, for this storm and also ϕ' and λ' the Latitude and Longitude of the point on the earth's surface cut by the Resultant. North Latitude and Longitude East of Greenwich are considered positive. The results are given in the accompanying table.

75TH MEAN TIME.		R	ϕ'	χ'
	h			
August 11	0	40	−15	− 28
	1	159	25	−118
	2	216	35	−145
	3	856	7	−120
	4	565	−72	− 20
	5	743	−78	−139
	6	302	−24	− 68
	7	128	−51	14
	8	217	−61	− 51
	9	130	−31	− 17
	10	428	−40	− 78
	11	323	−49	−105
	12	53	−30	−153
	13	57	66	90
	14	112	−11	−146
	15	27	−45	106
	16	34	−16	87
	17	41	−49	− 4
	18	32	−15	77
	19	141	14	74
	20	144	12	118
	21	455	− 9	−136
	22	90	34	163
	23	95	75	− 15
	24	219	−12	− 66
August 12	1	386	−39	− 47
	2	223	−46	− 44
	3	315	−57	− 29
	4	132	−39	− 61
	6	29	−61	− 90
	8	28	−60	−126
	10	30	−63	−141
	12	30	−40	−110
	14	43	−34	− 54

At first the Impressed Force was acting from a point a little north of the equator in the Pacific Ocean but at 4h August 11 had shifted far to the south and also eastward, and held this position very close until nearly 12h. From 12h to 23h changes in direction were large and frequent after which the Impressed Force came from the region of 40° to 60° S. Lat. and 40° to 100° W. Long. A reduced copy of this storm is given in the accompanying plate.

During June sunspots were very numerous and active but small. In July both the number of groups and the number of spots were considerably less than in June, whilst in August, although the number of groups were about the same as July the spots in the groups were more numerous.

Very few reports of the aurora were made from the Meteorological observatories in June and July, and the majority of these were for the 22nd of July, when a moderate magnetic storm occurred In August reports were more numerous, and especially for the 11th, 18th, 19th and 28th, and on each of these dates magnetic storms were recorded. W. E. W. J.


Lat. 45° 47' N. Long. 75°16' W.
Aincourt Vertical Force
Aincourt Declination August 10, 11, 1919
75th Meridian Time
Lat. 54°37' N. Long. 113°21' W.
Meanook Declination

Photographic Record of the great magnetic disturbance of Aug. 11-12, 1919, made at Agincourt and Meanook Observatories.

ASTRONOMICAL NOTES.

Lille Observatory Under the Germans.

Observatoire de l'Université de Lille,
Hem (Nord), 1919, June 13.

Dear Mr. "Oxford Note-Book,"—

Looking over *The Observatory* number of last month, I see the reports of the German observatories. In spite of the War, one sees that work is proceeding, and that in one case "an unusual amount of fresh apparatus, mostly of a minor type," has been received.

Reading these informations reminds me that you kindly suggested some time ago (*The Observatory*, No. 535) that I should give a report of the state of the Lille Observatory—the only French observatory which fell into German hands.

The damage caused by the officers who occupied the Observatory has been officially "constaté" by the Préfecture of Lille:—

Portable Instruments—All taken or destroyed.

Transit-circle.—Object-glass, level, microscopes, eye-pieces taken. Micrometer in pieces.

Equatorial.—Graduated declination-circle cut through and bent, vernier torn off. Graduations of the hour-circle scratched with a point. Zero of the vernier cut off with a knife. The screw of the declination-clamp (38 mm. thick bent. The slow-motion screw in R.A. taken. All means of reading the circles destroyed. The position-micrometer in pieces and all eye-pieces and accessories taken.

Dome.—Shutters put out of shape and in such a state that they cannot be shut.

Clocks.—All French clocks taken except one, which has had a liquid poured into the works.

Library.—347 books taken, mostly of the most scientific character. *Cartes du Ciel* commandeered. (I enclose a piece which will show the use they were put to.) Charts such as Argelander's Atlas cut to pieces. *Linen* cover cut from backs of books.

Offices.—Desks forced and emptied; typewriter, duplicators, publications, papers taken.

Meteorologic.—All registering instruments and others taken.

Park.—1337 trees cut; branches and poles made for grenade practice.

Habitation.—Like any other occupied by the Germans.

I want you to know that the Observatory was always occupied by highly-ranked officers. The clever destruction to the instruments and selection from the library (Chauvenet's 'Astronomy,' &c.) shows that these were educated men; they were doctors, engineers, and aviators.

These "selections" have been so complete as not even to forget the best specimens of my collection of local lepidoptera.

I had fears that the Observatory would be destroyed and my work stopped, and these fears have been realized, for, although the buildings stand, the ingenious way in which *every instrument has been put out of action*, has, indeed, made it impossible for me to do anything else than walk up and down the garden and look at the stars on fine nights. Yours sincerely,

Robert Jonckheere.

—From "The Observatory".

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

The Discovery of Comets.

In the history of the discovery of comets there are many interesting episodes, but none more striking than one which occurred during last August. Rev. Joel H. Metcalf is a successful minister of Winchester, Mass., but is also an enthusiastic astronomer and a very competent builder of telescopes. He himself makes the difficult and tedious computations required in designing a high-class telescope objective and then grinds and polishes the lenses. Some of his instruments are of considerable size and are of superior quality.

Having returned from service with the Y.M.C.A. in France, he went for a vacation at South Hero, Vermont, taking with him a smaller telescope of his own construction. At about midnight of August 20 he discovered a comet, and on the second day after, during the evening of August 22, he found another. In addition, during his sweeping of the sky he found a third, which, however, turned out to be Kopff's Comet, already announced. Thus in less than 48 hours Mr. Metcalf found three comets,—surely a record! In previous years he had discovered four more.

When sufficient observations had accumulated the orbits of these comets were computed, and it was then seen that the first of Mr. Metcalf's trio was one which was discovered by Brorsen at Altona in 1847 and which was expected to return in 1822. Its period is almost the same as that of Halley's Comet. When found by Metcalf it was near the Great Square of Pegasus and moving northward. It was hazy in appearance and difficult to recognize.

The second comet is believed to be entirely new. It was in Boötes, near Arcturus, had a bright nucleus, and later became visible to the naked eye under favorable conditions. It was independently discovered by Borrelly at Marseilles on the following day, August 23.

Some years ago, when the present writer was at the Lick Observatory, he learned some interesting information regarding the discovery of the comet 1882 I by C. S. Wells, at the Dudley Observatory, Albany, N.Y., on March 17, 1882.

After passing his third examination at Dartmouth College, Wells went to the Dudley Observatory as a volunteer assistant, Lewis Boss being director. Next year, after graduation, he became a regular assistant. For a number of years Warner, of Rochester, N.Y., had given $200 to the first discoverer of each new comet. But the prize had not been announced for 1882, and although it was offered later, Wells did not receive it.

Wells first swept the sky with a comet seeker, but becoming tired of that, he said he would take the 12-inch telescope and hunt for a faint one. For some time the search was continued, and at last by peculiar good fortune he detected a faint hazy object. The time was in the morning, not far from dawn. He examined it again, to make sure of it, and then went to call the director, who, however was not at home and it could not be shown to him. Next night was cloudy, but on the one following he was able to show it to Boss. Wells, however, was so nervous and excited that he could not measure its position. This was done by Boss who then announced the discovery by telegraph.

As is well known, this comet proved to be somewhat remarkable. Until then only hydrocarbon bands had been recognized in the cometary spectrum, but in this they were quite faint, while a continuous spectrum was seen. A little later the well-known sodium lines were recognized, and indeed they became the chief feature of the spectrum.

Quite recently in these columns (October 1917, p. 359) reference was made to a remarkable discovery of a comet by Perrine at the Lick Observatory on February 15, 1896. On translating a message received in cipher from Europe an error of 6° in right ascension was made, and Perrine, on pointing the 12-inch telescope at the *false position* actually saw a new comet, which was moving rapidly and which at that moment 'swam into his ken.'

A Puzzling Phenomenon with a Simple Explanation.

When anything happens there is a reason for it, even in the case of a gasoline engine, and generally the explanation is quite simple. A good example of this is given in a letter received by the present writer from Mr. H. W. Barker, the General Treasurer of the Society. It is as follows:

A recent article in "The Globe" from the pen of Mr. Peter McArthur, describing a strange phenomenon—namely, the illumination of the clouds, long after sunset, by a light which he was unable to explain—brings to mind a somewhat similar riddle which puzzled me for almost a year, but which I believe I have now solved. My home is just beyond the eastern limit of Toronto, a little back from, and about one hundred and fifty feet higher than, Lake Ontario. One night in the summer of 1918, I saw a strange light, resembling the aurora, but coming from the east instead of the north. Ribbons of shifting light played on the clouds, the direction changing slightly from time to time. I watched it for ten or fifteen minutes until it disappeared. A week or two later the phenomenon appeared again. I could find no explanation, nor could others whom I consulted. Months went by, and again I saw the 'auroral' glow. The light shot upward towards the zenith, now steady, now shifting, just like the northern lights, but always proceeding from the east. Half an hour afterwards I heard a train coming over the hill from Scarboro' Junction to York. A few nights afterwards the light appeared again, and in half an hour as before, along came a train from the east. I am now satisfied that I have solved the riddle, this strange phenomenon was nothing else than the head-light of the locomotive playing upon the clouds as the train proceeded westward from Pickering and Port Union to Toronto! I have been wondering if Peter McArthur's puzzle could have a similar solution.

Appointment at Ottawa.

Mr. Francois Henroteau has been appointed as Assistant Astronomer in the Dominion Observatory, Ottawa. Mr. Henroteau was formerly attached to the Royal Observatory at Brussels, and escaped from Belgium just besore the German occupation. During the war he held positions at Lick, Ann Arbor and Allegheny Observatories.

C. A. C.